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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

BUS AND TRUCK LUBRICATION

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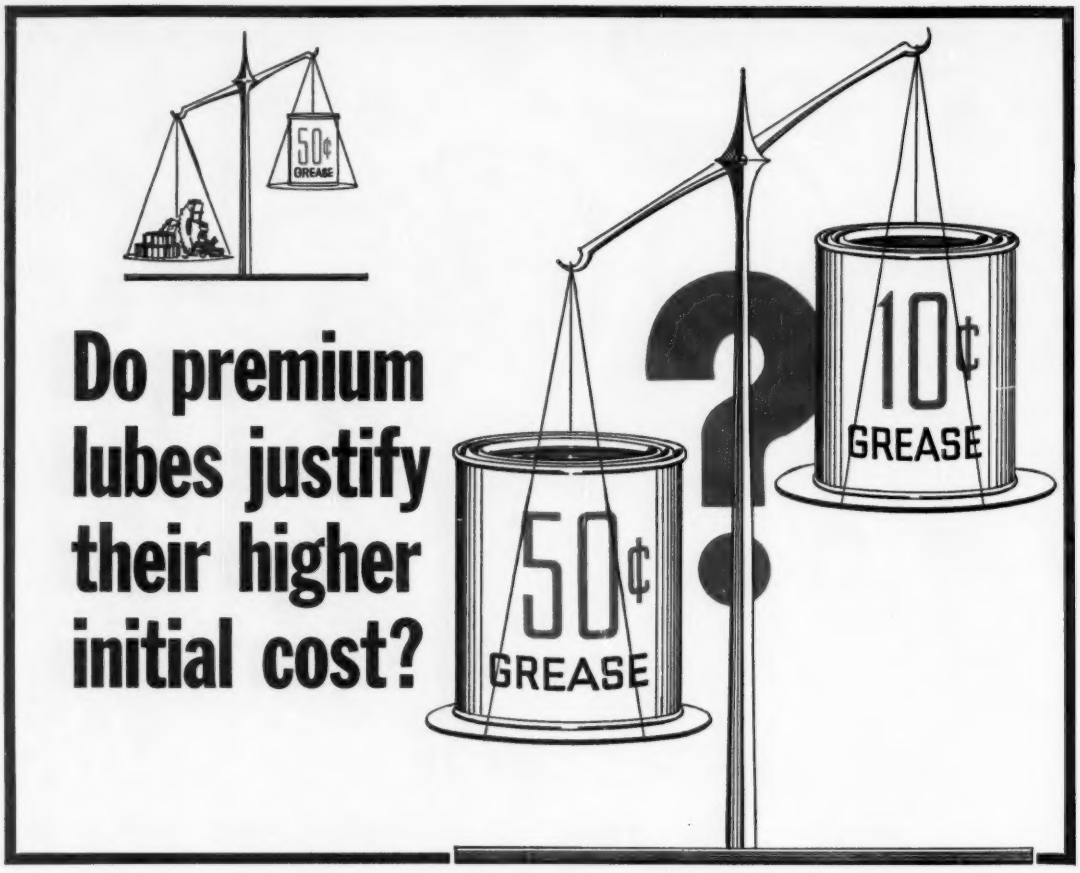

Across the country, an increasing number of truck operators are now spending as much as 35 cents a pound for premium grease when they could get an ordinary grease for as little as 10 cents. The same situation applies to motor oils —truckers are spending as much as 75 cents a gallon more for premium oils. This can be an increase in costs of more than 1,000 dollars a year for a large fleet. How do they justify the additional expense?

Cost-conscious operators give this reason: Premium lubricants allow them to stretch intervals between overhauls. They feel that paying 25 cents extra for grease, such as Marfak Multi-Purpose, for example, is worth it if it stays put long enough to save them a 30 dollar garage bill.

The same holds true for motor oils. Truck operators are now willing to pay a premium for oils with detergent and anti-oxidation additives simply because these high-grade oils will postpone the necessity for ring jobs and other expensive motor repairs. Basically, more and more truck operators today are coming to the conclusion that the extra money they spend for premium lubricants can save five to ten times that amount in less frequent repair bills and longer life for their equipment.

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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BUS AND TRUCK LUBRICATION

THE steady growth of the truck and bus industry is clearly shown by the yearly registration figures in Figure 1: from 1948 to 1958 registrations increased nearly 50 per cent. Although 1959 figures are not available, during 1958 over 11,000,000 trucks and buses were operating in the United States. Over this same period, the desire for improved acceleration, higher average road speeds, increased grade climbing ability and increased payloads has brought about many technological advances. Engines are designed with greater power and durability. To take advantage of the increased engine power and transmit it efficiently to the rear wheels has necessitated, in many cases, redesign of transmissions and rear axles.

Petroleum products have played a vital role in this progress. Through close cooperation with truck and bus manufacturers, the petroleum industry has encouraged mechanical developments by producing high quality motor oils, gear lubricants and chassis and wheel bearing greases. It is the purpose of this article to review the lubrication requirements of buses and trucks. Off-the-road and contractor equipment have been previously[1] discussed and will be excluded.

ENGINE OPERATING CONDITIONS

The conditions under which an engine is operated have a considerable influence on the duties which an oil must perform. Therefore, before attempting a discussion of crankcase oils it might be well to consider the different types of equipment that we are concerned with and the degree to which their service and lubricant performance requirements differ from each other.

There are perhaps three general categories into which both bus and truck operations can be classified. The first is the "stop-and-go" type of operation with much idling such as found in door-to-door delivery truck and city bus service. Typical units of this type are shown in Figures 2 and 3. The second category includes delivery trucks of the type shown in Figure 4 in short run service. The third involves sustained-speed open-highway driving as in inter-city or cross country bus and truck operations. Vehicles used in service of this type are shown in Figures 5, 6 and 7.

With the exception of the city bus, most of the equipment used in the first two categories is powered by gasoline engines. Equipment used in the third category is becoming increasingly diesel powered.

Stop-and-Go Operation

Some types of service commonly thought of in the past as being very light are actually quite severe from the engine lubrication standpoint in that they promote both rapid wear and objectionable deposits. This applies especially to stop-and-go service of light trucks with *gasoline* engines and to light load, cold operation of any engine. Tests have indicated that in such service, crankcase temperatures rarely exceed 140°F.

With such low temperature operation, the water

[1] Magazine Lubrication, March 1956, March 1960.

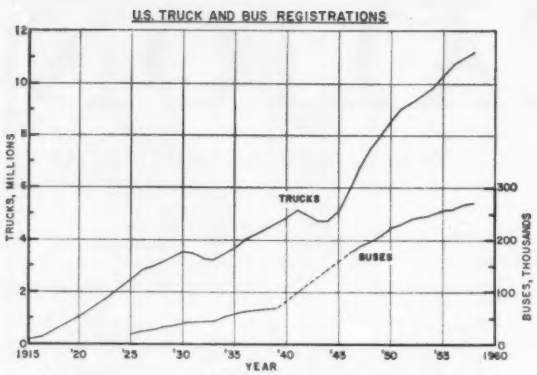


Figure 1 — Trend of U. S. bus and truck registrations.

vapor formed during combustion of the fuel-air mixture condenses on the relatively cold cylinder walls and is carried into the crankcase by the action of the oil rings. Other contaminants which enter the oil when operating the engine cold are unburned and partially burned fuel and fuel soot, the results of incomplete combustion. Unless prevented by a suitable oil, these materials emulsify with the water to form a soft paste known as "mayonnaise" or low temperature sludge which deposits on parts of the engine, clogs oil pump intake screens and oil lines and causes severe engine damage. Ring sticking and valve sticking can also occur. Water also combines with the products of incomplete combustion to form acidic materials which rust piston rings and cylinder walls, and may corrode bearings. Most engine wear is the result of rust. In addition to the undesirable effects already mentioned, the oil becomes diluted with unburned liquid fuel which washes some of the oil from the cylinder walls, causes scuffing, excessive "friction" wear, and bearing damage. Thus if cold engine operation is continued too long, dilution may reduce the viscosity of all the oil to such an extent that it can no longer provide a sufficiently thick film between moving parts. This further promotes engine wear and higher oil consumption.

Oil is rarely oxidized to any extent but is heavily contaminated with fuel combustion residues. Fortunately these evil effects can be combatted successfully by using a highly detergent rust-preventive "heavy duty" oil and draining it frequently.

Courtesy of Divco Truck Div. of Divco-Wayne Corp.

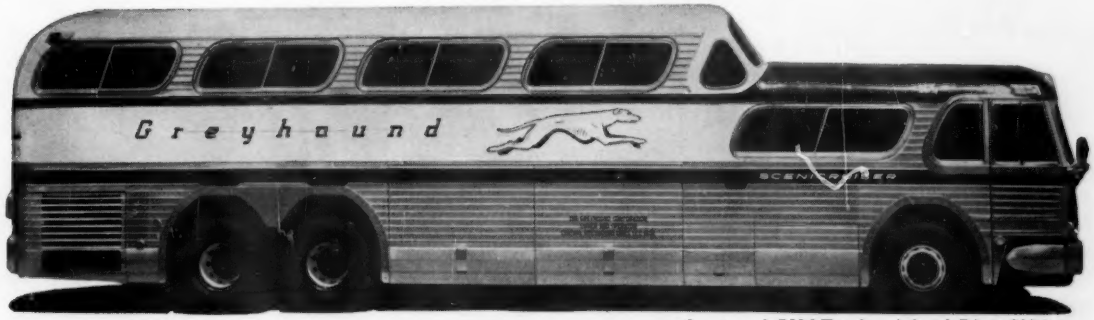
Figure 2 — Door-to-door type delivery truck.

Courtesy of Superior Coach Corp.

Figure 3 — City type bus.

Courtesy of Mack Trucks Inc.

Figure 4 — City-suburban delivery truck with van body.



Courtesy of GMC Truck and Coach Div., GMC

Figure 5 — Inter City and cross country bus.

Courtesy of Ford Motor Company

Figure 6 — Tractor and semi-trailer.

Short-Run Truck Service

This type of service is characterized by city and suburban delivery trucks which are powered with *gasoline* engines and which make frequent deliveries or pick-ups interspersed with short periods of driving in city traffic. During the pick-up or delivery period, the engine is usually shut off and little idling occurs, however much of the driving is still done with a relatively "cold" engine. Under this type of operation the factors affecting engine operation and crankcase oil requirements are very similar to those in effect under the stop-and-go type of operation. Cylinder wall corrosion and crankcase oil contamination are again the major problems which are solved with a detergent rust-preventive "heavy duty" crankcase oil and draining it regularly.

Sustained Operation

This type of service is associated with long distance truck and both long distance and city bus operations. Cold starts and engine idling occur only infrequently. Reasonably high engine operating temperatures are maintained so that contamination of the oil with water and unburned fuel is slight. Over-the-road trucks and buses are increasingly

diesel powered: city buses are usually diesel-powered but in special circumstances liquefied petroleum gas ("LPG") and gasoline engines may be used. Diesel engines are somewhat more severe on crankcase oil than gasoline engines, and this point will be discussed in detail in the forthcoming section dealing with engine oil performance requirements.

The severity of service under sustained high speed operation depends upon a combination of several factors. Continuous operation under road load and moderate air temperatures usually represent very favorable driving conditions. In such service, the engine operates at efficient temperatures with good fuel combustion, hence ordinary sludge formation is minimal. However the high and sustained crankcase temperatures tend to oxidize and thicken an ordinary crankcase oil and to form varnish and other acidic oil oxidation products which can stick piston rings and corrode some types of bearing alloys. Supercharging an engine to obtain greater power magnifies this tendency. Thus this type of service may severely affect the oil but in quite different manner from stop-and-go service. Heavy duty oils not only contain oxidation inhibitors to combat oil oxidation, but their detergent additives keep oil oxidation products in suspension and thereby prevent varnish deposits until the additives are exhausted.

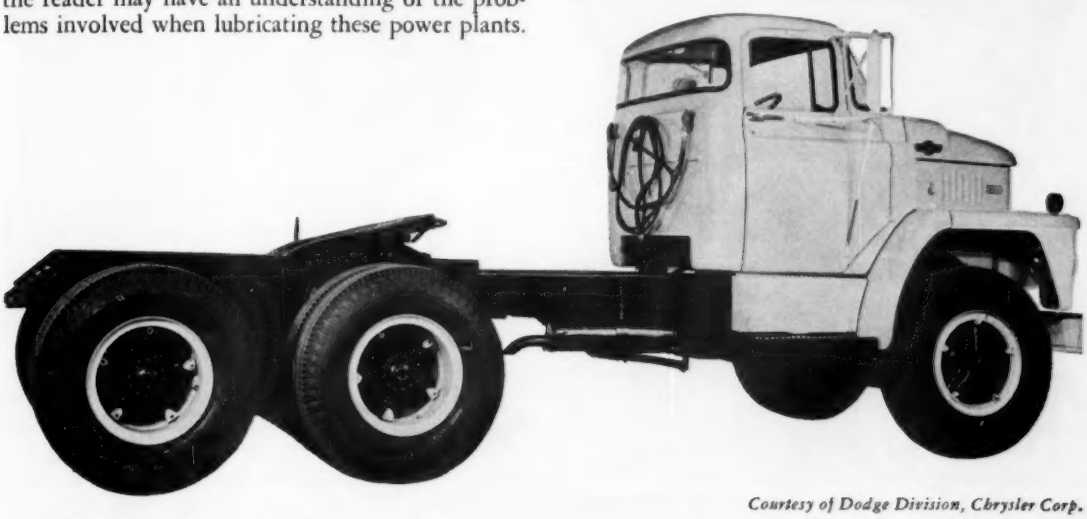
ENGINE TYPES

As mentioned earlier, busses and trucks are generally powered by either gasoline, diesel or (in a few instances) LPG engines. While it is not planned to enter into a detailed discussion of the design of bus and truck engines nor to comment on their operating cycles, a general review of the types of engines used in these vehicles is necessary so that the reader may have an understanding of the problems involved when lubricating these power plants. It can be generally said the diesel engines are more severe than gasoline engines because of differences in the operating cycles of the two types of engines. The increased combustion pressures of the diesel, its less volatile fuel and its tendency to form more combustion carbon all impose added burdens on the lubricating oil. Unlike gasoline engines, diesels actually utilize only about three-fourths of their intake air for combustion and the remaining surplus highly-heated air is available to attack the lubricating oil.

Recent bus and truck diesel engines have resorted to supercharging as a method of obtaining more power from a given sized package. In addition some diesel engines operate on the two cycle principle which by approximately doubling the power output also adds a greater heat load to the crankcase oil. Thus if comparative tests were made between an automotive gasoline and a high speed high output diesel engine, the diesel engine would require a more highly developed crankcase oil. In other words the diesel crankcase oil would also be most satisfactory for the gasoline engine but the reverse would be unlikely. As will be seen later, most high quality crankcase oils are equally suitable for either severe gasoline engine or moderate diesel engine service. Typical bus and truck engines are shown in Figures 8, 9, 10 and 11.

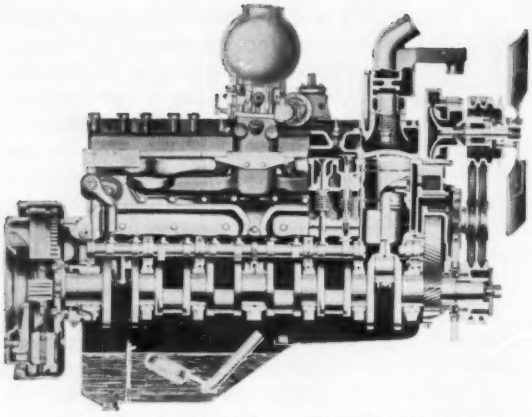
ENGINE OIL PERFORMANCE REQUIREMENTS

Engine oil quality may be described in a number of different ways and there is no single completely acceptable method. For example, the term "Heavy Duty" is a fairly exact and widely used but now somewhat obsolete term which is usually associated with the original U.S. Army Specification USA



Courtesy of Dodge Division, Chrysler Corp.

Figure 7 — Heavy six wheeled tractor-truck. Note fifth wheel, air brake hoses and electric cables to connect the semi-trailer.



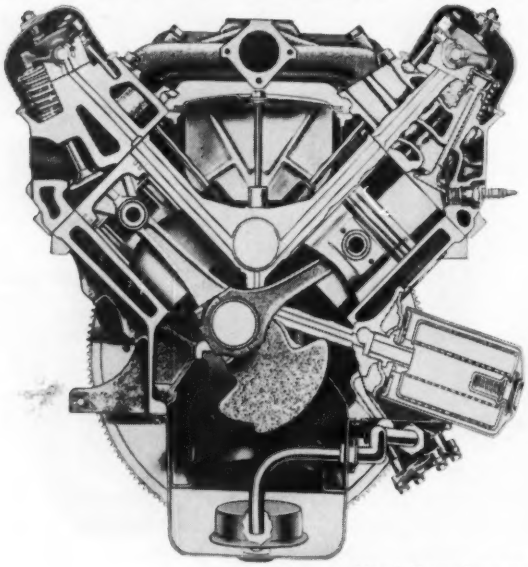
Courtesy of Autocar Div., White Motor Company

Figure 8 — Six cylinder L-head gasoline truck engine.

2-104 which defined oil quality on the basis of certain performance tests. Other descriptions or specifications have been proposed by individual equipment manufacturers. The most prominent current lubricant specifications are described in the following.

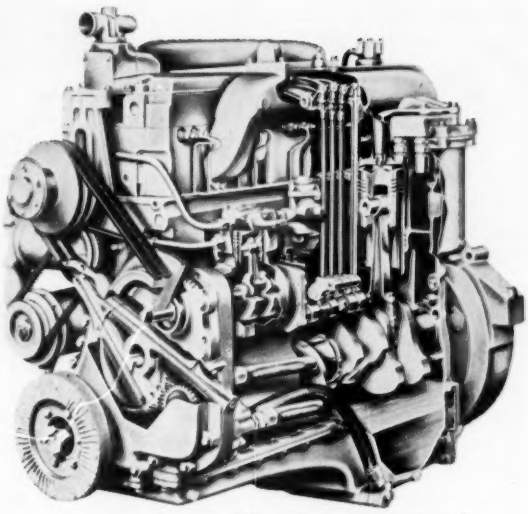
MIL-L-2104A Amendment 1

Currently, an acceptable heavy duty oil is generally recognized as an oil which complies with the performance requirements of Military Specification MIL-L-2104A Amendment 1. As indicated by number similarity, this Specification is essentially similar to the previous MIL-O-2104 and to the original Army Specification USA 2-104. To qualify, motor oils must pass two specific engine tests (the CRC L-4-1252 and the CRC L-1-6149) in addition to other chemical and physical tests. The CRC L-4-1252 test (commonly abbreviated to "L-4") is conducted in a six cylinder gasoline engine and provides information on bearing corrosion, oil oxidation and high temperature engine deposits in gasoline service. The CRC L-1 test is conducted in a



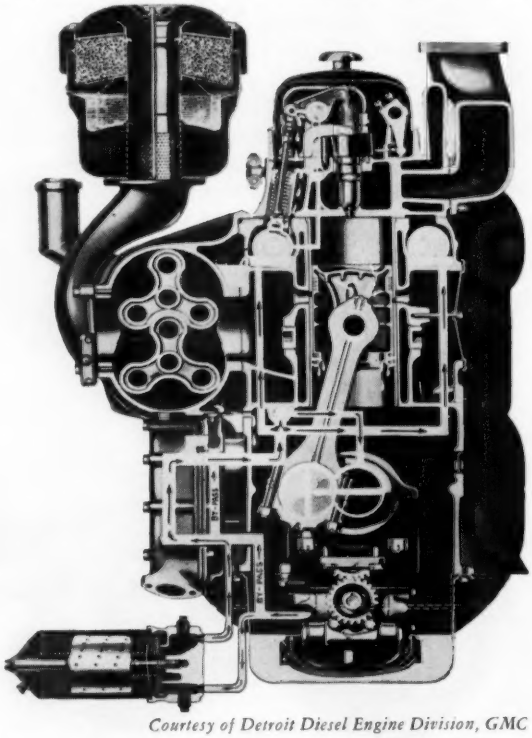
Courtesy of Ford Motor Company

Figure 9 — V-8 overhead valve gasoline truck engine.



Courtesy of Cummins Engine Company, Inc.

Figure 10 — Naturally aspirated six cylinder overhead valve diesel truck engine.



Courtesy of Detroit Diesel Engine Division, GMC

Figure 11 — Two-stroke cycle diesel truck engine with blower scavenging.

TABLE I

COMPARISON OF OPERATING CONDITIONS
CATERPILLAR SINGLE-CYLINDER DIESEL
TEST ENGINES

Conditions	Procedure		
	L-1	1-D	1-G
Test period, hrs	480	480	480
Oil change period, hrs	120	120	120
Engine speed, rpm	1000	1200	1800
Jacket outlet, °F	175	200	190
Oil to bearings, °F	145	175	205
Exhaust back pressure	..... less than 1" Hg.		
BTU input, avg/minute	2950	5600	5850
BHP	19.8	42	42
Air intake temperature, °F	Ambient	200	255
Air intake pressure, "Hg.	Atmospheric	14	23
Sulfur content of fuel, %	*	0.95-1.05	0.35 min

*0.35 min for MIL-L-2104A Amendment 1
0.95-1.05 for MIL-L-2104A Amendment 1, Supplement I

single cylinder diesel test engine using a fuel with a minimum sulfur content of 0.35%, and provides information on ring sticking, deposits and wear in diesel service. The letters "CRC" are an abbreviation of "Coordinating Research Council," a joint organization formed by the Society of Automotive Engineers and the American Petroleum Institute.

Oils meeting the requirements of this specification are also suitable for use in gasoline powered engines operating under moderate temperatures and severe conditions such as might be encountered in suburban and inter-city bus and truck service.

MIL-L-2104A Supplement 1

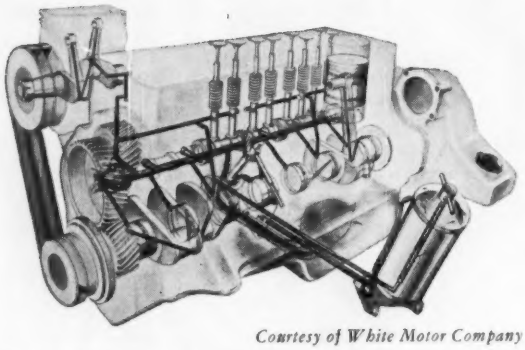
"Supplement 1" is an industry-wide term but, at present, does not refer to any specific military or engine builder specification. However, motor oils are listed as "Supplement 1" oils if, in addition to passing the CRC L-4 test, they also pass the special L-1 test of the MIL-L-2104A Amend. 1 Specification which is conducted with a high sulfur (1% app.) diesel fuel instead of the normal 0.35% sulfur. These lubricants generally have a higher additive content than MIL-L-2104A oils and will provide satisfactory performance under more severe operating conditions such as might be found in diesel engine service which includes some start and stop operation in city hauling as well as suburban and inter-city bus and truck service. Such lubricants are also very satisfactory when used in gasoline engines and provide an additional margin of performance over that obtained from MIL-L-2104A, Amendment 1 heavy duty oils.

"Superior Lubricants" (Series 3)

In 1947-48 Caterpillar Tractor Company issued a "Superior Lubricants" (Series 2) Specification for lubricants to be used in heavy duty diesel engines which are operated on high sulfur fuels under particularly adverse conditions. A special supercharged single cylinder engine test procedure to evaluate these oils with improved characteristics became known as the Caterpillar 1-D Supercharged Engine Test. These lubricants performed very satisfactorily and, compared to MIL-L-2104A Amend. 1 and Supplement 1 oils, provided marked improvements in reduction of deposits and wear with high sulfur fuels.

However, when new and even higher output engines were developed, it became obvious that in order to maintain satisfactory performance a new lubricant type was needed. Therefore, in 1956, the Superior Lubricants (Series 2) Specification was superseded by a Superior Lubricants (Series 3) Specification which required not only passing the Caterpillar 1-D but also the Caterpillar 1-G Supercharged Engine Test. Operating conditions of the 1-D and 1-G test procedures are compared with those for the CRC L-1 in Table I.

In February 1959, a new Military Specification, MIL-L-45199 (Ord), was issued which is essentially the same as that specified by the Caterpillar Tractor Company for Superior Lubricants (Series 3), with certain exceptions. In addition to the 1-D and 1-G engine tests, the military requires that the lubricant pass the previously described CRC L-4-1252 (gasoline) engine test.



Courtesy of White Motor Company

Figure 12 — Typical lubrication system of a gasoline powered truck engine.

Lubricants meeting Series 3 and its Military counterpart, MIL-L-45199 (Ord) are recommended primarily for high output supercharged diesel engines operating under severe service conditions. However, these lubricants are also very satisfactory for gasoline engines since they give even greater protection against fuel deposits, oxidation, corrosion and wear than is available in lubricants designed solely for gasoline engines.

Selection of a Motor Oil

In selecting a motor oil there are two major considerations which affect the final decision. The first is the "weight" or viscosity of the oil and the second is the "quality" of the oil.

The viscosity classifications of motor oils have been defined by the Society of Automotive Engineers (SAE)[2]. Generally, this classification system provides for seven different viscosity grades of motor oil ranging from the lightest, SAE 5W to the heaviest, SAE 50. Viscosity is an important characteristic of motor oils and the correct viscosity grade is usually recommended by the manufacturer so as to provide the best service under different conditions of temperature and operation. It should be remembered that viscosity is a physical characteristic of the oil and does in no way reflect oil quality.

Oil quality is defined either by specification as indicated above or by the oil refiner's assertion that his particular oil will perform satisfactorily under the various service classifications established by the American Petroleum Institute (API)[2]. This service classification is broadly broken down into two general categories: one of gasoline engine oils and the other for diesel engine oils. Each of these general categories is further subdivided into three classes ranging from the least to the most severe service. For example, the three classes under the gasoline engine category are ML, MM and MS for "*motor* light" service, "*motor* medium" service and "*motor* severe" service, respectively. The order of relative severity and capability is obvious. Similarly the diesel engine oil category is divided into the DG, DM and DS classes. These correspond to "*diesel* good," "*diesel* medium" and "*diesel* severe" service, respectively. Those oils which are designed to give satisfactory performance in the more severe service categories generally contain a greater percentage of additive materials. The additives used are specially designed to provide corrosion protection for cylinder walls and bearings, adequate detergency to prevent the formation of engine sludge and varnish, good engine oil oxidation resistance, resistance to foaming, and reduction of engine wear.

Both fleet and laboratory tests have indicated repeatedly that the better the oil, the less wear, corrosion and engine deposits are obtained. Many fleets use oils meeting the Supplement I or higher requirements and have found by experience that less maintenance is required and longer engine life is obtained from using such oils.

In the selection of a motor oil for a particular type of service, two basic factors must be considered. The first is the temperature at which the engine is to be started and operated and the second is the type of service to which the engine is to be subjected. Engines of busses etc., which are stored outside should be supplied with a light viscosity oil to facilitate starting or preferably some means of keeping engine jackets fairly warm so that a higher viscosity oil can be used.

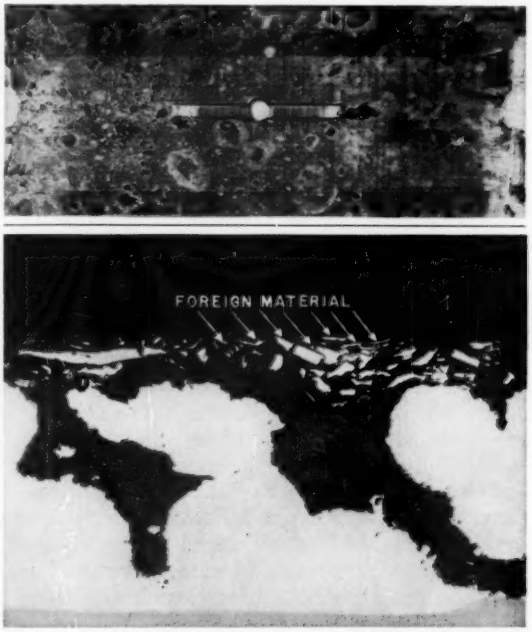
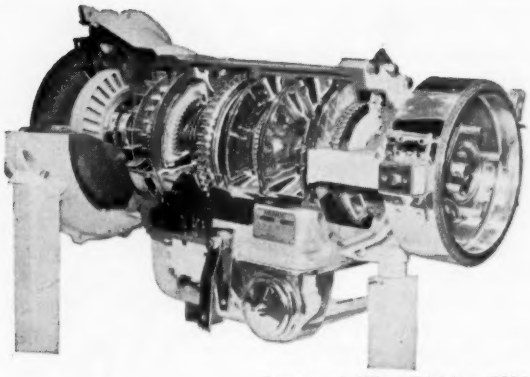


Figure 13 — Engine connecting rod bearing damage caused by imbedment of foreign material particles carried by dirty lubricating oil. Upper photo has been photographically "unwrapped" to retain focus throughout. Lower photomicrograph of cross section shows imbedments in bearing wearing surface.

[2]See Magazine Lubrication, April 1960.



Courtesy of Allison Division, GMC

Figure 14 — Six speed fully automatic transmission.

While a low viscosity oil is desired for ease of starting, it is almost universally true that once started the engine temperature remains high. Therefore for this reason a heavier viscosity oil is desirable. In order to obtain the benefits of easy starting and proper viscosity under operating temperatures some fleets are using the new multi-grade oils like the 10W-30 and 20W-40 which have the advantage of acting like light oils when cold but provide the proper viscosity for high temperature operation when hot.

LPG Engine Lubrication Requirements

When LPG was first introduced as a fuel for automotive type engines, claims were made that simple straight mineral oils could be used and that even with these, oil drains could be extended or possibly eliminated. However, experience soon proved that such was not the case. Even though LPG is a gas at the carburetor, complete combustion is not always obtained under all operating conditions. Accordingly, products of incomplete combustion can and do form, thereby affecting engine operation. Corrosion of engine parts (particularly corrodible type bearings) formation of engine deposits and contamination of crankcase oil are three results of incomplete fuel combustion.

Oil oxidation is another factor that has to be considered since even the highest quality straight mineral oils do not perform satisfactorily in high temperature service.

From the foregoing it is apparent that the modern automotive type LPG engine requires special consideration if proper lubrication is to be obtained. For best operation, Supplement I quality oil should be used although there are many applications where MIL-L-2104A Amend. 1 oil will perform with complete success.

Oil Drains

Oil drain periods have always been a source of considerable discussion. The reason for this is that these periods vary considerably depending on the type of operation. What may be satisfactory for a given truck when operated by one company may be totally inadequate when the same model truck is operated by another company under different service conditions.

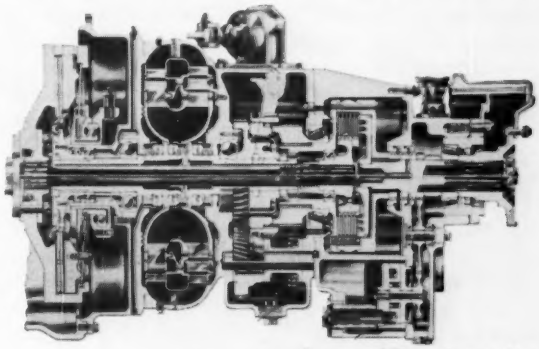
The reason oil is drained is to remove from the engine those contaminants which have entered the oil as a result of use. These contaminants may be water, dust, sand, unburned and partly burned fuel, fuel soot, and oil oxidation products. Modern detergent oils are designed to prevent fuel soot and oxidized contaminants from depositing, i.e. by keeping them in suspension so that they will be removed from the engine at the time of oil drain. Some people still think that an oil which looks clean after a considerable period of use is a good oil. Nothing could be farther from the truth. The contaminants mentioned above are *in the engine:* if they are not being held by the oil they are depositing somewhere, probably in the crankcase and valve chambers where they are forming sludge and other undesirable deposits.

Many modern engines are equipped with oil filters of some type as shown in Figure 12. The use of these filters materially assists in removing solid contaminants from the oil but they are not a substitute for periodic oil drains in removing contaminants from the engine.

However, oil filters do serve an important function in keeping at least a majority of the oil that is circulated free from large particles that may damage the bearing surfaces. Figure 13 shows two views of a bearing that failed due to the presence of foreign material in the oil. An oil filter in proper operating condition might have prevented this.

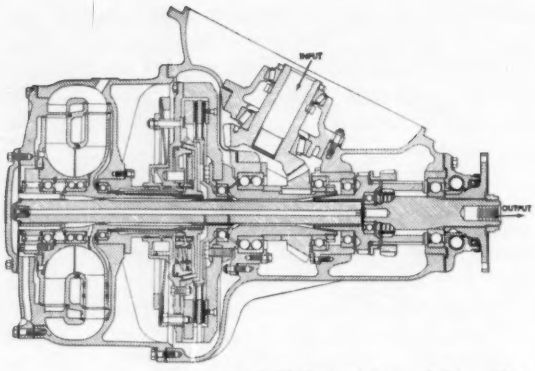
AUTOMATIC TRANSMISSION LUBRICATION

Although some type of hydraulic or automatic transmission is now available for practically all classes of buses and trucks, their use is still limited



Courtesy of Dana Corporation

Figure 15 — Turbo-Matic torque convertor automatic transmission.



Courtesy of GMC Truck & Coach Div., GMC

Figure 16 — General Motors Vee type torque convertor automatic transmission.

mainly to light duty delivery type vehicles and some city buses where a combination of frequent gear shifts and additional driver duties like fare-collecting occurs. Some of the several different types of automatic transmssion in use are illustrated in Figures 14, 15 and 16.

While each type of transmission does have certain specific requirements which must be met by the lubricant used, they all require that the oil have certain basic features to assure good transmission operation. First, of course, it must lubricate. In all automatic transmissions gear shifting and converter lock-out functions are carried out through the application of oil under pressure to clutch pistons and bands. In addition the oil is used in the torque converters and fluid couplings that are used in most modern transmissions. In these units considerable heating of the oil occurs due to kinetic energy. Thus the oil must not only act as a lubricant and hydraulic medium but also as a coolant to maintain proper operating temperatures in the transmission.

Another important requirement of an automatic transmission lubricant is oxidation stability or in other words, the ability to resist the oxidation which may occur as a result of the high temperatures encountered. The proper and smooth operation of any automatic transmission depends on the precise timing of each of the shifting operations. These events are controlled by an intricate valve system which operates with very small clearances. Oil oxidation materials, in fact contaminants of any type will tend to jam or slow the action of these control valves and result in either rough shifting or extensive damage to the transmission.

The transmission manufacturer usually recommends a type of oil or fluid which, by his test, has been found to be satisfactory in his units. In addition, he also establishes the drain periods which should not be exceeded. Usually, if the service is very severe, shorter drain periods are recommended.

Automatic Transmission Fluids, Type A-Suffix A

The original Type A Specification, issued in 1949, was based on existing satisfactory products, and many passenger car type automatic transmissions have since been designed and developed using such a fluid. Under this specification fluids were subjected to extensive laboratory, engine and transmission tests by an independent laboratory: each fluid which met or exceeded the test requirements was assigned an individual qualification number, such as AQ ATF 102, which was embossed or stencilled on all its containers. Fluids of this type had high oxidation and foam resistance, oiliness, low pour points, some EP properties and a very high viscosity index so necessary to maintain the proper viscosity through a wide temperature range for best operation, particularly when hydraulic controls are actuated by the fluid.

However, as automatic transmission complexity and engine horsepower continued to increase some instances were encountered in which automatic transmission fluids fully qualified under the existing Type A Specification resulted in sludge formation under severe service conditions in the new transmissions. Improved products were developed to alleviate these conditions and a modified specication identified as "Automatic Transmission Fluid, Type A, Suffix A" was issued in November 1957 to cover these improved products. The test requirements of the new specification are more severe and, to qualify, fluids must possess improved high temperature oxidation stability in addition to the requirements of the original specification.

To qualify, fluids must meet rigid physical and chemical characteristics and be satisfactory in special engine and transmission tests conducted at an independent laboratory. Fluids so qualifying are also assigned a distinctive AQ ATF number which is followed (suffixed) by the letter A. This identification stamped on each container assures the customer that the product meets the specification requirements. Although suitable for most automatic transmissions, products of this type are generally recommended primarily for passenger car and light delivery truck automatic transmissions.

Hydraulic Transmission Fluid, Type C-1

In 1955 Allison Division of GMC introduced a specification for a fluid for use in the heavy duty truck, bus and earth-moving vehicle hydraulic transmissions they manufacture. In these applications Type A and Type A Suffix A products show exceptionally satisfactory performance, however, this service does not demand all of the characteristics of these fluids. By reducing the fluid requirements, less costly ingredients can be used.

The Allison specification was designated "Hydraulic Transmission Fluid, Type C." Many heavy duty motor oils in the SAE 10W and SAE 20-20W viscosity classification, in addition to some special fluids, adequately met the specification requirements. Subsequent service showed that fluids in the SAE 10W classification are more desirable. Consequently, in December 1959, the specification was modified accordingly and updated in test procedures. Fluid designation Hydraulic Fluid, Type C-1 has been assigned to products meeting the requirements of the modified specification. Other manufacturers also recommend products of this type for their heavy duty torque converters.

Torque Fluids

Many buses, especially of the city type, have final drive units which include a torque converter. This unit is usually a part of a two speed series automatic transmission such as shown in Figures 15 and 16. When starting from rest the unit is transmitting all power through the torque converter. At a predetermined speed it automatically shifts into direct all-mechanical drive through the engagement of a friction clutch. Some units provide for driver control of this shift point.

The fluids originally used in these torque converters in heavy duty service were kerosine, No. 2 household fuel or diesel fuel. In some diesel-engined coaches, fluid was drawn from the engine's fuel tank, then burned in the engine. Experience gradually demonstrated however that these non-specialized materials left much to be desired, and in several instances caused maintenance and operating difficulties that were unjustly blamed on the then "new fangled" converter. Being non-specialized and intended for other uses, these fluids entirely lacked those qualities which are now recognized as essential to torque fluids. Most of these materials oxidized excessively, were of insufficient viscosity, and contributed to cavitation and foaming. Some oxidized so badly and became so deteriorated that they attacked the bronze turbine blading in the converter. None of them were capable of preventing rust formation from water that condensed in the converter systems of irregularly used coaches.

Since even a high quality mineral oil is incapable by itself of fulfilling all requirements of a torque fluid, specially designed fluids were developed for this application. Typical tests on a fluid of this type are as follows:

Gravity, °API	26.4
Flash, PM, °F	300
Viscosity, SUS at 100°F	65
Viscosity, SUS at 210°F	35
Pour, ASTM, °F	–40
Foam Test, CRC	None
Rusting	None

In some units under severe operating conditions it was found that a higher viscosity lubricant was required. Fluids having all of the previous characteristics but with the following viscosities have been found to be satisfactory under severe high temperature conditions:

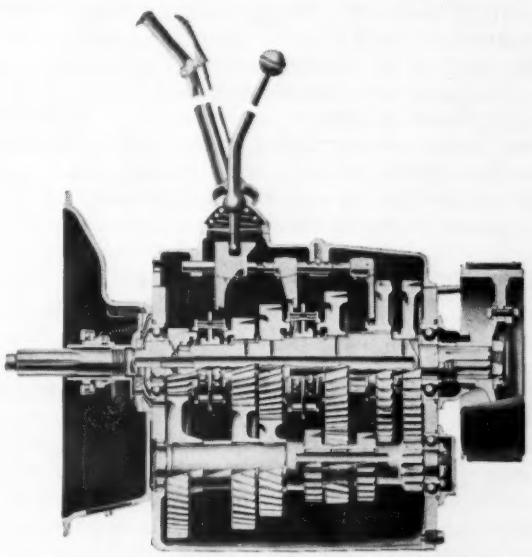
Viscosity, SUS at 100°F	90-110
Viscosity, SUS at 210°F	38 (Min.)

Products of this latter type are frequently used in city busses and stationary torque converters.

CONVENTIONAL TRANSMISSION LUBRICATION

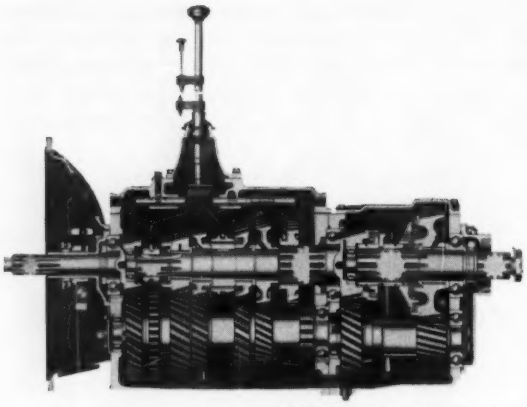
Conventional (straight mechanical) transmissions still remain in general use for truck operation and continue to be used for inter-city bus and truck service which is characterized by sustained speed with but few stops. While light delivery truck and school bus transmissions may have only 3 or 4 forward speeds, larger trucks and busses use transmissions with 5 to as many as 15 forward speeds. Typical units of the latter types are shown in Figures 17, 18 and 19.

The lubrication requirements of conventional transmissions are controlled by several factors. The first is the temperature range over which the specific lubricant must operate. If the range is too wide, at the lowest temperatures the oil may thicken so that it will not flow and thus cause the gears and bearings to run dry and wear excessively. At high temperatures the oil may thin excessively and thus not provide sufficient wear protection for the gears and bearings. For this reason, the viscosity grade of oils used in conventional transmissions



Courtesy of Clark Equipment Co.

Figure 17 — Five speed manual truck transmission.



Courtesy of Fuller Manufacturing Company

Figure 18 — Ten speed manual truck transmission.

is varied according to the expected ambient temperatures.

The second factor to be taken into consideration is the oxidation stability of the oil. Under severe conditions of service where high temperatures occur, the oil may oxidize and thicken. All high quality motor oils and gear oils are sufficiently oxidation-resistant to prevent this.

Although some manufacturers still specify a highly refined straight mineral type gear lubricant, there is an increasing trend toward the use of high quality SAE 50 engine oils of the "heavy duty" type. The good oxidation resistance, anti-corrosive and anti-rust properties of these oils make them ideally suited for lubrication of conventional transmissions. However, in transmissions, where higher gear loading occurs, and particularly in auxiliary units, gear lubricants having Extreme Pressure (EP) properties should be used. These lubricants are discussed more fully under Rear Axle Lubrication.

Transmission gear cases must be drained periodically, the interval depending on the design and type of service encountered. Component and vehicle manufacturers generally offer a suggested level check and drain period for their transmissions as a guide for proper lubrication.

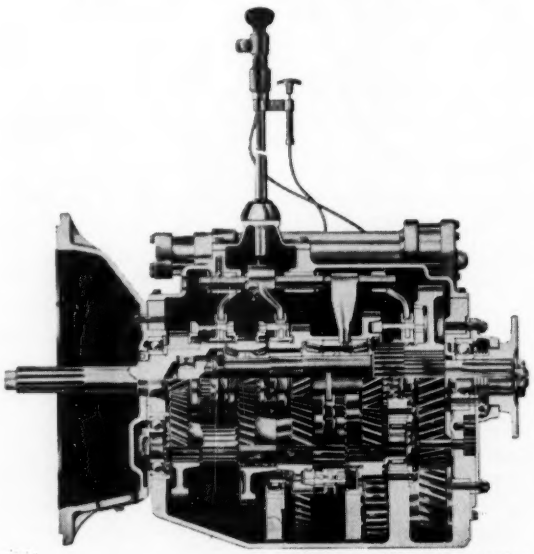
REAR AXLE LUBRICATION

Rear axles today contain most of the common types of gears singly or in combination depending on the service requirement. The basic torque-multiplying mechanism in all rear axles uses either straight bevel, spiral bevel, hypoid or worm and wheel gear combinations. In addition all provide some form of differential action. To obtain greater speed reduction or torque multiplication, some of these units also include spur, helical or herringbone reduction gear sets. To further complicate the mechanism but to obtain a wider range of operation, levers and appropriate gear sets may be included to provide more than one speed reduction. Examples of the various arrangements possible are shown in Figure 20. These units are generally used in heavy duty over-the-road trucks. Buses and light delivery trucks usually use a simple differential unit without additional speed reduction units like that shown in the upper left hand picture in Figure 20.

Before discussing the specific lubricants to be used in the many different types of differential units available, it might be well to discuss the conditions under which many differentials must operate. All mechanical devices have friction. In a differential this friction comes from rubbing of the gear teeth against each other, churning of the lubricant and, to a slight extent, from the ball or roller bearings. In fast moving vehicles this frictional heat is removed by the passage of air over the housing. In slow moving vehicles where air cooling is not sufficient the temperature rises. Temperatures of 250°F are not uncommon in truck differentials when climbing long hills in low gear.

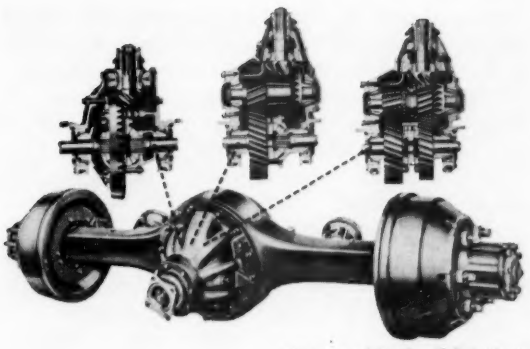
It is therefore obvious that one of the primary requirements of a good differential fluid is the ability to resist the oxidizing effect of these high temperatures. All high grade differential lubricants have this characteristic.

An equally important requirement of a differential lubricant is the ability to prevent scoring of the gear teeth under heavy loads. To do this a lubricant must have Extreme Pressure or EP properties which will prevent the scoring by the formation of a very thin sacrificial coating on the gear teeth at the point where metal to metal contact is occurring. This ability is often imparted to a lub-



Courtesy of Dana Corporation

Figure 19 — Twelve speed manual truck transmission.



Courtesy of Rockwell Std. Corp.

Figure 20 — "Three for one" rear axle assembly and cross-sectional views of interchangeable differential units. Upper left view: conventional single-speed. Center view: double reduction single-speed. Right view: double reduction two-speed.

ricant by incorporating EP additives containing such materials as sulfur or chlorine. Occasionally lead soaps are also used as "oiliness" additives, particularly when the lubricant is to be used in a worm drive type of differential such as is shown in Figure 21.

To take care of the many possible combinations of gears and service, the Lubricants Committee of the Division of Marketing of the API have set up gear lubricant classifications which are used by the SAE. These are applicable only to conventional transmissions and axles, and not to the previously-discussed automatic transmissions. These classifications are as follows:

"Regular Type Gear Lubricant — This term designates gear lubricants generally suitable for use in automotive transmissions and in most spiral-bevel and worm-gear differentials."

"Worm Type Gear Lubricant — This term designates gear lubricants generally suitable for use in truck-type worm-gear rear axles under very severe conditions of service."

"Mild Type EP Gear Lubricant — This term designates gear lubricants having load-carrying properties suitable for many automotive transmissions and spiral-bevel differentials under severe conditions of speed and load."

"Multipurpose Type Gear Lubricants (API Service GL 4) — This term designates lubricants which have properties required to provide satisfactory lubrication of hypoid gears and conventional differentials, including adequate load carrying ability for protection of such gears in sustained high speed and/or high torque service in modern high powered passenger cars and trucks. They are suitable for use in spiral-bevel gears, many transmissions, and for worm gears in some types of service. Such lubricants are identified as meeting API Service GL 4."

These definitions are somewhat broad and include all of the gear lubricants that are normally suitable for the various services encountered. Since the above are service classifications and not specifications, it is the responsibility of the lubricant supplier to insure that his product meets the definitions. The military, however, have set up a specification for gear lubricants which adequately defines a lubricant suitable for military service.

MIL-L-002105A (Ord)

Previous gear lubricants meeting MIL-L-2105 were found to lack the desired oxidation stability and load carrying ability required to successfully operate in the newer military equipment where higher loads and temperatures were encountered. Therefore, the Department of the Army conducted an extensive testing program in an effort to establish a specification which would adequately define the type of lubricant which would be satisfactory in their equipment.

As a result of this test work MIL-L-2105 was revised and issued as MIL-L-002105A (Ord) and contained tests specifically designed to determine the oxidation stability, load carrying ability and rust prevention properties of lubricants. Products qualified against this specification are considered satisfactory for military equipment.

Lubricants qualified against MIL-L-002105A are gaining manufacturer acceptance, are now widely available at service stations, and will provide excellent service.

CHASSIS LUBRICATION

Chassis lubrication is more important than ever before due to closer tolerances, heavier vehicle weights and higher road speeds. Driving schedules in today's vehicles impose severe requirements upon the chassis lubricant. To perform satisfactorily it must be cohesive and adhesive; that is, it must be able to stick to itself and to the chassis parts. It must spread freely over the parts and must also form an effective seal to prevent the entrance of dirt and water. It must be water resistant so that it will not wash away when splashed with water from the road. The chassis lubricant must also have sufficient load carrying capacity, so that it will not squeeze out under even the most severe dynamic loads.

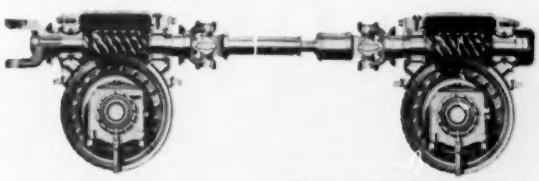


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Figure 21 — Single reduction worm gear tandem differentials. Note connecting shaft with its two universal joints and slip joint.

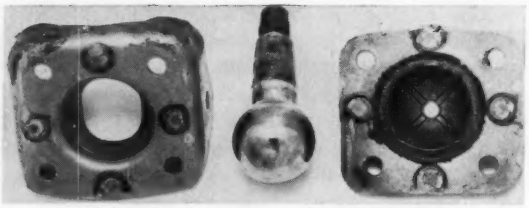

Figure 22 — Disassembled front-suspension ball joint unit.

A good multipurpose heavy duty type grease can also be used as the chassis lubricant. These are generally lithium base products that are water insoluble, have relatively high melting points, and have good low temperature performance. The term "multipurpose" covers a great deal of territory and the integrity and reputation of the lubricant supplier are the best assurance the user has that a given grease meets all these stringent requirements.

Ball Joints

A relative newcomer to the field of chassis lubrication is the ball joint employed in front end suspension systems. A typical ball joint is shown in Figure 22. At first, it appeared that this component would offer no new lubrication problems. However, as experience was gained with its use, this was proven false. It was found that the normal chassis lubricant would satisfy the joint's requirement immediately after lubrication, but did not last as long as desired. Apparently, the grease squeezed from between the ball and socket, resulting in an increase in torque required to turn the ball and in a dry "chucking" noise which was audible when driving the vehicle over rough roads. Certain types of greases and the use of special additives took care of this difficulty, but the elementary problem was one of design. When design changes were made it was found that regular chassis lubricants, properly applied, again provided satisfactory service.

Universal Joints — Spline Shafts

Universal joints that are enclosed and mounted in back of the transmission gear box are usually lubricated by the gear box lubricant. Other universal joints may have a lubricant reservoir in the cross or trunnions. Some have sufficient lubricant capacity so that the original supply is good for the life of the vehicle or replenished after long periods of service such as 20-30,000 miles. A lubrication fitting is usually provided for this purpose, however, some types require disassembly for lubrication. A relief valve or hole is usually provided to prevent overlubrication and/or damage to the seals from excessive pressure during application of the lubricant.

Universal joints have been affected by the trend of rising horsepower and early failures have been experienced. The universal joint failure shown in Figure 23 was attributed to excessive load which broke through the film of an inadequate grease, prevented it from reforming and permitted severe fretting corrosion[4]. Fortunately, products are available with higher load carrying and feedability characteristics to alleviate this situation.

When seals are effective, universals can be lubricated with a heavy oil of the SAE 140 grade, however most joints are grease lubricated. Since the grease is subjected to severe centrifugal action however, it must completely resist any tendency towards separation into its component oil and soap.

The spline shafts are always closed at one end by a disc or cap fitted to the yoke of the universal and at the other end by a packed seal and are usually equipped with independent lubrication fittings. Spline shafts are usually grease lubricated although an SAE 140 grade oil is specified for some. If not of the long period type, lubrication periods should be at the time of chassis lubrication.

Other Chassis Components

A few chassis components and accessories are normally lubricated with a hand oil can at the same time as the grease points. Normally an SAE 20 grade motor oil of the type used in the engine is suitable for this application.

STEERING GEAR LUBRICATION

Power steering has been used in rugged off-the-highway trucks and military vehicles for many years but it was not until the early '50's that it was used for on-the-highway vehicles. Power steering now is usually supplied as original equipment for transit and inter-city buses and is optionally available for all other classes of trucks and buses.

In a power steering unit, the fluid must act as a hydraulic medium and as a lubricant. It must have good temperature-viscosity characteristics to insure ease of steering over a wide temperature range, satisfactory anti-wear properties to guarantee long pump and equipment life, suitable air rejection properties to promote uniform steering effort under a variety of operating conditions, good oxidation stability to prevent deposition at elevated tempera-

[4]See Magazine Lubrication, August 1955 ("Fretting and Fretting Corrosion").

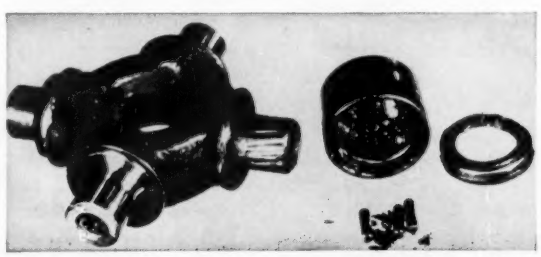

Figure 23 — Failed univeral joint showing brinelling of one bearing surface.

Figure 24 — Wheel bearing failure caused by contaminated grease. Note the severely heated outer end of the bearing spindle and the complete disintegration of the outer bearing. See Figure 25.

tures, and compatability with a variety of seal and hose materials to prevent their early deterioration. From these, it may be seen that the requirements imposed on a power steering gear fluid are similar in many respects to those of automatic transmission fluids. It is only natural, therefore, that automatic transmission fluids should be used in this application and such has been the case. Power steering systems should be checked at 1000 mile intervals with drain and refill periods recommended for from 15,000 to 25,000 miles depending on the type of unit and the particular installation.

Conventional steering gear boxes require various lubricants such as semi-fluid greases or fluid gear oils depending on the design of the unit. The frequency of lubrication is usually at the time of chassis lubrication.

WHEEL BEARING LUBRICATION

Lubrication of the wheel bearings involves the proper application of the correct quantity of a suitable lubricant and the mechanical know how of handling and adjusting a precision mechanism. Each phase is equally important to attain maximum bearing life. An anti-friction bearing will give long life if it is properly cleaned, lubricated, adjusted and kept free of abrasive and other contaminants. A premature wheel bearing failure due to lubricant contamination is shown in Figure 24, and a photomicrograph of the contaminant, mainly sand, is shown in Figure 25.

Modern sodium, calcium, and lithium soap multi-purpose greases are most widely used for wheel bearing application. Since greases of different bases may not be compatible and cause leakage, old grease should always be completely removed before re-lubricating. The cleaned bearing should also be carefully inspected and replaced as a unit if chipped balls or rolls, or incipient spalling of either race is found. Repacking is best accomplished with a packer cone which is faster, cleaner and more thorough than hand packing.

The necessity for placing wheel bearing grease in the wheel hub is a matter of considerable controversy due to the dangers of over-packing. It is not necessary to pack the hub full of grease since this will cause aeration of the grease and possible leakage. However, a light smear on the spindle and hub cavity surfaces should be used to prevent rust.

SIMPLIFIED LUBRICATION PLAN

One of the problems confronting a fleet owner is his choice of lubricants. Petroleum companies have made available hundreds of different types and grades of lubricants represented by thousands of different brand names to meet the demands of industry. Vehicle manufacturers prepare lubrication charts recommending the various grades and types of lubricants which they feel are best suited for their equipment. However, there has been little progress throughout industry toward standardizing lubrication recommendations. For example, one manufacturer will specify certain grades of lubricants for use on his equipment, while another manufacturer of the same type of equipment with similar basic lubrication requirements may recommend an entirely different set of products. Therefore, if the recommendations were followed to the letter in a fleet of mixed vehicles, many more products would be apparently required than could be handled conveniently.

A careful study of the requirements by a competent lubrication engineer will reveal, in most cases, that one product can replace a number of others, and thus permit a simplified lubrication plan. For example, as shown in Table 2, four or five products of good quality can handle most requirements of a transit bus or truck fleet. Such

Figure 25 — Photomicrograph of quartz sand contaminant extracted from grease used to "lubricate" wheel bearing shown in Figure 24.

TABLE II
SIMPLIFIED LUBRICATION PLAN

Part Requiring Lubrication	Lubricant Type Used	
	Truck Fleet	Bus Fleet
Engines (gasoline, LPG, diesel) and miscellaneous accessories, such as air cleaners, generators, air compressors, etc.	MIL-L-2104A Supplement I (API Service MS, DG, or DM) Superior Lubricants (Series 3) for use with high sulfur fuels (API Service DS)	
Transmissions		
Manual conventional	Multipurpose Gear Lubricant	
Bus, torque converter type		Torque Fluid
Passenger car type automatic	Automatic Transmission Fluid Type A, Suffix A	
Differentials Gear Boxes Steering Gears	Multipurpose Gear Lubricant	
Chassis parts, universals, wheel bearings	Multipurpose Grease No. 2	
Power steering units	Automatic Transmission Fluid Type A, Suffix A	

simplification is desirable since it reduces the inventory that must be carried and, with fewer products, the chances of confusion, misapplication and equipment damage are greatly reduced.

Plans of this type are of special importance in large fleet operations where a specific type of equipment may be serviced at several different points throughout the fleet system. A simplified lubrication plan will not only effectively reduce the necessity of stocking many different lubricants at each servicing point but will also assure that all of the lubricants used throughout the entire maintenance system are compatible.

In addition such a plan materially reduces the time required for lubrication since frequent changes among different lubricants are no longer necessary when servicing a vehicle. This allows more time for inspection and preventive maintenance. Such procedures are extremely important in that they assure maximum utilization of equipment and minimize expensive and time consuming road breakdowns with their attendant emergencies.

SUMMARY

As a result of the close cooperation that exists between the lubricant and the equipment manufacturers, suitable lubricants are widely available to take care of the diverse requirements of any bus or truck operation. Proper application and use of these lubricants is a must if the equipment is to operate satisfactorily and efficiently. Good maintenance demands a relubrication schedule that is in keeping with the environment and operation. Good maintenance will insure that the equipment is in proper operating condition with minimum cost. To assure this a simplified lubrication plan using only top quality lubricants from reputable suppliers should be installed and followed.

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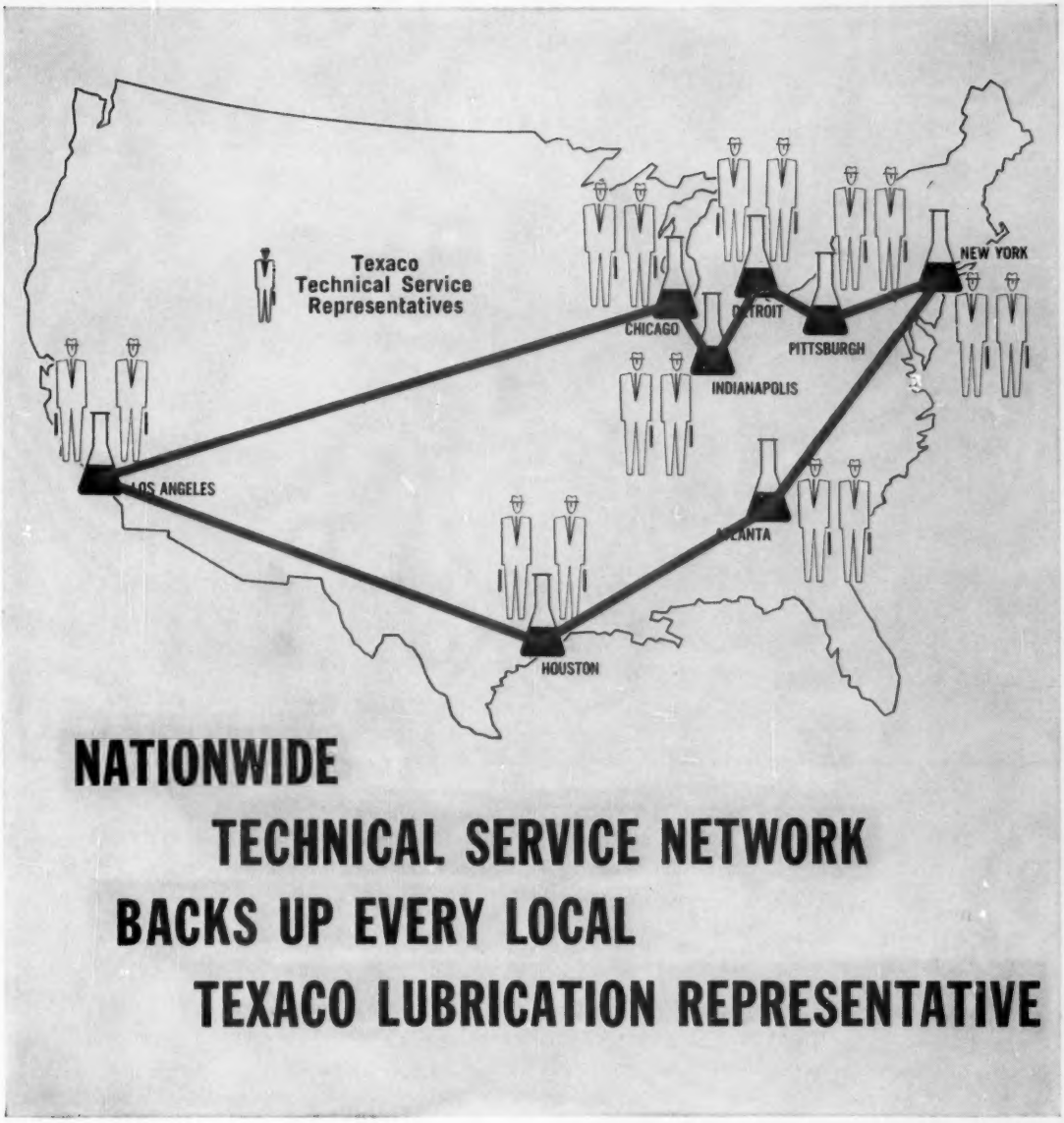

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